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OPTIMAL PROVISION OF PUBLIC GOODS UNDER COSTLY EXCLUSION AND CORRUPTION

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Laws and rules that underlie and enhance public safety, clean environments and public goods are promulgated with the intent of promoting social welfare. The extent to which they do so depends on the effectiveness of their enforcement. Enforcement activities are, however, limited by incentives for corruption. Whenever corruption emerges, society faces a trade off between social costs that rules are designed to avoid and social costs that arise from corruption.

How can society design enforcement activities, public or private, simultaneously to minimize the occurrence of violations and social costs from corruption? What are the socially optimal amounts of public goods to be provided? To answer these questions, this paper investigates provision of a public good in the presence of corruption. In a world of costly deterrence but no corruption, a clever use of fines will solve the problems of optimal exclusion. In the presence of corruptible enforcers, however, fines cannot be set sufficiently high to make randomized enforcement possible. In these cases the optimal arrangement is either to abandon enforcement entirely or to set the fine equal to the sum of the marginal cost of inspection and the marginal social cost of crowding and have all participants pay the fine. In effect, this is equivalent to private enforcement of exclusion by a monopolist as long as individuals agree on the cost of crowding. Relative to the first best level of usage for the public good, overenforcement of exclusion leads to underusage and free entry leads to overusage. We establish conditions for each of these to be the outcome. We conjecture that in the case where participants disagree on the costs of crowding, the optimal outcome can be achieved by privatizing enforcement but allowing the government to maintain the power to set fines.

For policy purposes,. the fundamental insights of this paper are as follows: In the presence of corruption, the policy instruments available to the government are much more limited than they appear in textbook descriptions of public finance. Increased taxes and fines may generate no additional revenues, since they will simply induce increased under-the-table payments. However, if the primary purpose of the tax or fine were to deter certain behavior by the public, then the fact that the actual revenues may not reach the government may not be the primary consideration, since the increased demands by corrupt officials will still serve as deterrents. Nonetheless, the effectiveness of the deterrent will in general be reduced by corruption.

seen clear evidence in the Brazilian data that such reallocation occurred over the period examined.

4. If corruption is a problem, incentive plans are unlikely to reduce it since the rewards they offer will not be enough to tempt corrupt officials to refrain from corruption.

5. Other characteristics of the economy -- elimination of hyperinflation, improved indexation of tax payments, reduction of tax rates -- are likely to have greater effect on the collection of taxes than will even large-scale reforms of the tax collection system.

The main limitation on the conclusions we have reached stems from the extent of the data available. Given the limited number of years of pre-reform data available, an alternative hypothesis could not be dismissed: that the relative increase in productivity from lower initial levels was due to "errors in variables." In other words, regions or taxes observed to have low yields in 1988 are disproportionately likely to be transiently low; the supposed growth may simply be a subsequent return to normal yields. This alternative possibility could be decisively eliminated by using additional years of data to establish a long-run average level of colleciton. If individual incentives play the role described above, then we may find further confirmation in the pattern of more recent collection activities. Adjustments since 1992 have effectively eliminated the individual incentives while making the group incentives even larger. The model we have described in this paper would therefore predict that attempts to allocate labor more effectively would continue unabated, but the productivity per employee would decline and the discrepancy between high and low productivity sectors would return.

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We examine optimal provision of a public good in the presence of corruption. In our model, exclusion although costly is socially desirable because of rivalry in consumption. Previous studies have examined costly exclusion in the presence of no corruption. In this case, severe fines can be used to achieve the first best outcome. However, the effectiveness of exclusion depends on exclusion enforcers' incentives to take bribes from lawbreakers. In the presence of corruption, the provider's decision becomes the choice of one of two alternatives: overenforcement of exclusion or free entry. Relative to the first best level of usage for the public good, overenforcement of exclusion leads to underusage and free entry leads to overusage. We establish conditions for each of these to be the outcome; in either case as long as the population agrees on the cost of crowding, the second best optimum is equivalent to private enforcement of exclusion by a monopolistic provider.

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INTRODUCTION

Laws and rules that underlie and enhance public safety, clean environments and public goods are elaborated with the intent of promoting social welfare. The extent to which they do so depends on the effectiveness of their enforcement. Enforcement activities are, however, limited by incentives for corruption. Whenever corruption emerges, society faces a trade off between social costs that rules are designed to prevent or control and social costs that arise from corruption.

How can society design enforcement activities, public or private, to minimize simultaneously the occurrence of violations and social costs from corruption, what are the socially optimal amounts of public goods to be provided? This paper addresses these questions. We examine the allocation and enforcement of exclusion subject to corruption incentives for a public good characterized by feasible but costly excludability. We consider as an example the case of optimal usage of a common resource, where exclusion is costly.

We find that incentives for corruption forces the government to choose one of two alternatives: free entry or exclusion subject to overenforcement. In other words, either the government sets fines very low (perhaps zero) and does not control access at all or the government sets fines sufficiently high so that overenforcement results. We show that the arrangement which arises with exclusion subject to overenforcement is socially desirable if and only if the net social gains from restricting usage (i.e., total benefits under exclusion minus total benefits in absence of exclusion) outweigh the social cost of overenforcement. Thus, the likelihood that exclusion will be implemented depends positively on the benefits of users who are not excluded and negatively on the social cost of overenforcement.

The optimal arrangement under exclusion subject to overenforcement features: a number of participants which is determined by the condition that the marginal user's benefits must equate the sum of marginal inspection cost and marginal social cost of crowding; a fine equal to the marginal user's benefits; and a number of inspections equal to the optimal number of participants.

The optimal arrangement under exclusion subject to overenforcement is second best since it takes into account the social cost of overenforcement. In other words, compared to the arrangement which emerges under costly but honest and diligent enforcement, the arrangement under exclusion subject to overenforcement leads to a smaller number of participants and to a greater expected fine.

Our example is a lake which is used for fishing by the population of the community where it is situated. Suppose that users derive disutility from sharing the lake with other users (for example because of a common pool externality). Because restricting access to those who value fishing the most may be socially desirable, the community's government contemplates the possibility of controlling access to the lake. To exclude some individuals from usage, the government may hire an inspector whose function is to undertake random inspections and charge a fine for usage to every user he catches. Therefore, a violation occurs whenever someone uses the lake and corruption occurs whenever the inspector accepts a bribe from a user he catches. A user who is caught has incentives to bribe the inspector in order to circumvent the fine for usage.

The simplified model of the main portion of the text assumes that the only instrument that the government can use for restricting entry is a fine. An addendum to the paper demonstrates that the main results continue to hold when we allow the government to use fees and fines simultaneously, provided we add an extra level of heterogeneity to the population.

LITERATURE REVIEW

Our research builds on the literature on optimal provision of rivalrous and excludable public goods subject to costly exclusion and on the literature on collusion behavior in law enforcement. However, as we demonstrate below, these two branches of literature dealt with the problems of optimal provision of public goods and the effectiveness of law enforcement separately. Our main contribution is to examine the extent at which these two problems interrelate.

Silva and Kahn (1993) is a good example of the literature on optimal provision of rivalrous and excludable public goods subject to costly exclusion. They examine the simultaneous choices of levels of excludability and public good provision taken by the producer of a public good. In their framework, the choice of excludability levels is a question of both exclusion technologies and incentives. The producer of the public good (principal) designs a mechanism that accounts for the possibility of consumers (agents) to free ride. They find that whenever agents are homogeneous the optimal degree of excludability is either zero or one; perfect exclusion always results if the good is provided. But if agents are heterogeneous, there will be circumstances where allowing some free riding is optimal. In any event, the public good will be underprovided relative to the conventional case where exclusion is costless. Since the free-riding fine is exogenously given and the inspector is honest and diligent, the issue of collusive behavior in the enforcement of fines does not arise.

Now we review some papers on the literature on collusive behavior in law enforcement. Becker and Stigler (1974) emphasize that the larger fines for violations are made the greater will be the incentives for public enforcers to engage in corrupt transactions with violators. To prevent corruption, they investigated two distinct solutions. First, the state should pay an enforcer a salary which equals the enforcer's opportunity wage plus an extra compensation for foregoing corrupt opportunities. The major drawback of this solution, however, is that the extra compensation the state should pay increases with the amount of bribes the enforcer forgoes which in turn increase in magnitude with the values of fines for violations.[1] The alternative to the first option of inducing good behavior from public enforcers is to let law enforcement to be carried out privately by competitive firms. Enforcement firms should be compensated with part or full value of fines levied against convicted violators and should pay the costs borne by acquitted persons. Because compensation is based on performance, there will be little incentive for private enforcers to engage in illicit bargains with violators.[2] Nevertheless, they argue that overenforcement may result from privatization of enforcement activities.[3]

Pashigian (1975) examines public policies that control both violations and bribery, which in his model are explicitly interrelated. He argues that the problems of violations and corruption must be dealt with simultaneously. For serious violations, attempts to reduce corruption by increasing the fines to corruption (where violators are liable) may lead to an increase in the severity of violations and thus raise the scale of bribes. To control corruption, he proposes, it is best to raise the fines for violations. This policy reduces the incidence of corruption by more effectively deterring violations.

Mookherjee and Png (1991) have extended Pashigian's analysis by allowing the law enforcer to choose enforcement effort and to be paid by commission. They study "...the trade off between eliminating corruption and reducing the primary harm" (p. 3). The authors investigate for a model consisting of the government, a public law enforcer and a polluter how to compensate the enforcer in order to eradicate corruption. Since in their model, as in Pashigian's, marginal increases in the fine for corruption leads to increases in the scale of bribery and perhaps to increases in the amount of pollution, the social optimal public policy becomes one of two alternatives. If fines for violations are sufficiently high, the government must privatize enforcement. If fines for violations are sufficiently low, the government must legalize the harmful activity. In any case, they argue, opportunities for corruption will be eliminated. However, since in their analysis the amount of damages caused by pollution from the firm is exogenous, the authors could not determine the optimal fine for pollution and the optimal level of total pollution to be permitted.

In short, these works suggest that opportunities for corruption should be reduced or eliminated. Society may achieve this goal by adopting one of three options available: (i) raise wages of law enforcers, (ii) privatize law enforcement or (iii) legalize the harmful activity. None of these works, however, explicitly deal with the issue of the optimal levels of public good provision (e.g., public safety) which result from the adoption of the options available. The social desirability of implementing any one of these public policies depends on the level of public good provided under every alternative. For example, private law enforcement will be socially preferable to legalized harmful activity whenever the social cost of overenforcement is smaller than the total benefits originated with the (over)effective restriction of the regulation. This comparison is meaningful, however, only to the extent that we can measure the levels of public good provision which result under both alternatives.

THE SETTING

A community possesses a lake which is used by its population for fishing. The utility derived by any user i of the lake is

$$m + u(i) - v(r),$$

where $m \geq 0$ denotes his consumption of money, $u(i)$ is his personal (idiosyncratic) benefit from using the lake and $v(r)$ is his utility from sharing the lake with r users. We assume that $v_r(r) \geq 0$ and $v_{rr}(r) \geq 0$. In what follows the population is ordered from 0 to P and we consider $u(i)$ as a decreasing function of i on [0, P].

In absence of any restriction to entry (i.e., everyone may use the lake), the lake will be used by r_o users such that the r_oth user is indifferent between using or not using the lake. In other words,

$$u(r_o) - v(r_o) = 0.$$

Henceforth, suppose $0 < r_o < P$. Thus, any user finds it desirable to restrict entry to the lake since his utility from usage decreases with the number of fishermen using the lake.

Suppose the community's government decides to control access to the lake. The government's goals are to determine the optimal number of users and deny access to any number of users in excess of the optimal number.

First consider the case where controlling access is costless. Then, the government solves the following problem:

$$\underset{\{r\}}{\text{Maximize}} \int_0^r u(i)di - rv(r) \tag{P1}$$

subject to: $r \geq 0$.

The first order condition which determines r*, the solution to (P1), is:

$$u(r^*) - v(r^*) = r^* v_r(r^*) \tag{1}$$

that is, r* is the number of users which equates marginal social benefit to marginal social cost from using the lake. Thus, the effective restriction of entry improves social welfare as long as $v_r(r_o) > 0$. As an example, if individuals are identical, then, with free entry all benefits are dissipated. Restricting entry allows those who are consumers to receive positive benefits.

Now consider two cases where restricting entry is costly: one where enforcement of the restriction is undertaken by honest and diligent enforcers and one where enforcement of the restriction is undertaken by enforcers who are not necessarily honest or diligent.

We start by examining the arrangement where enforcers are honest and diligent. The monitoring system is as follows. The government hires an inspector to catch users of the lake and charge them a fine f for usage. Inspections are undertaken at random and their extent is determined by the government, which also determines f. The inspector's cost of apprehending any user is c.

Individuals decide whether or not to use the lake. If individual i decides not to use the lake, his total utility equals his initial endowment of money m_o. If, on the other hand, individual i decides to use the lake, his expected utility is

$$p[m_o - f + u(i) - v(r)] + [1-p][m_o + u(i) - v(r)]$$

$$= m_o - p(I,r)f + u(i) - v(r),$$

where $p(I,r)$, the probability of individual i being caught by the inspector, depends positively on the number of inspections made, I, and negatively on the number of users, r. In the case of random sampling without replacement:

$$p(I,r) = \min[I/r,1].$$

We will assume this particular functional form for the probability of being apprehended in what follows.

Agent i uses the lake whenever it is advantageous to do so:

$$m_o - If/r + u(i) - v(r) \geq m_o$$

or

$$u(i) - v(r) \geq If/r \tag{2}$$

Individual rationality constraint (2) states that agent i uses the lake if the benefit from doing so is no less than the expected cost of being caught.

Since the government incurs the total cost Ic from restricting entry, its problem is as follows:

$$\underset{\{r,\ f,\ I\}}{\text{Maximize}} \int_0^r u(i)di - rv(r) - Ic \tag{P2}$$

subject to: $u(r) - v(r) = If/r$,

$r \geq 0$, $f \geq 0$, $I \geq 0$.

Tt can he verified that this problem is equivalent to the following problem:

$$\underset{\{r,\ f\}}{\text{Maximize}} \int_0^r u(i)di - rv(r) - rc(u(r) - v(r))/f \tag{P2'}$$

subject to: $r \geq 0$, $f \geq 0$.

Note that the objective function in (P2') improves as f gets larger. Strictly speaking, there is no maximum to this problem; loosely speaking, the best thing to do is to make fines greater and greater and number of inspections more and more rare, all the time balancing inspections and fines so as to encourage exactly the first best number of participants, which is determined by equation (1).

Next consider the arrangement where the inspector is neither necessarily honest nor necessarily diligent. This is a case where the inspector's effort and honesty are not observable by the government. Because of this moral hazard problem, the inspector has an incentive to pocket some of the fines he collects when the fine for usage is sufficiently high and has an incentive to shirk when the fine is sufficiently low.

To begin with we will consider a case where the government has no way at all or monitoring the inspector's behavior. The instruments at its disposal are simply: 1) the legal fine it establishes and 2) any payment to or from the inspector (since the government cannot monitor the inspector's behavior, such payments are perforce lump sum).

For concreteness, suppose the inspection technology works as follows: the inspector takes a picture of the individual he has caught. Such a picture is irrefutable evidence of the individual's action; if the inspector sends the picture to the government, the government will force the individual to pay the fine f. On the other hand, the inspector can bargain with the individual to hand over the evidence in return for a bribe. The outcome of such bargaining will depend on the abilities of the two individuals bargaining. To keep things simple in this paper, we assume that in the bargain, it is the inspector who extracts the complete surplus -- in other words, the individual pays him the value of the fine in exchange for the evidence Tn short, the inspector's balance is as follows: if the fine is lower than the cost of inspection, the inspector shirks and no one is caught. If the fine is greater than the cost of inspection, the inspector has an incentive to catch everybody and obtain a bribe of f from each.

The government, knowing of the inspector's incentives to either take bribes or shirk, knows that the effect of establishing a fine is really to establish the amount of bribe the inspector can collect. In this scenario, the government sets the fine for usage, the inspector chooses the number of inspections to be made and the number of users is determined endogenously given these parameters.

Since Ic is the social cost from inspection, the government's goal is to:

$$\underset{\{r,\ f,\ I\}}{\text{Maximize}} \int_0^r u(i)di - rv(r) - Ic \tag{P3}$$

subject to: $u(r) - v(r) = If/r,$

$I \in [0,r]$

$f > c$ implies $I = r$

$f < c$ implies $I = 0$

$f \geq 0.$

In principle, we would also need to consider the inspector's willingness to participate in the scheme; however, the government can always use lump sum transfers to the inspector to ensure the inspector's participation.

Thus, there are three cases to be examined: (i) $c > f$; (ii) $c < f$; (iii) $c = f$.

Case (i). This case is trivial since $c > f$ implies that $I = 0$. Then, $r = r_o$ (free entry).

Case (ii). When $c < f$, $I = r$. Then, the government's problem is:

$$\underset{\{r,\ f\}}{\text{Maximize}} \int_0^r u(i)di - rv(r) - rc \tag{P3.1}$$

subject to: $u(r) - v(r) = f,$

$r \geq 0.$

This is solved by choosing r^{**} to satisfy:

$$u(r^{**}) - v(r^{**}) - r^{**}v_r(r^{**}) - c = 0$$

or

$$u(r^{**}) - v(r^{**}) = c + r^{**}v_r(r^{**}) \tag{3}$$

and then setting $f^{**} = u(r^{**}) - v(r^{**})$.

Case (iii). When $c = f$, $I \in [0,r]$. Then, the problem is for the government to choose both r and I:

$$\underset{\{r,\ I\}}{\text{Maximize}} \int_0^r u(i)di - rv(r) - Ic \qquad \text{(P3.2)}$$

subject to: $u(r) - v(r) = Ic/r$,

$r \geq I \geq 0$.

Thus, the problem may be simplified to:

$$\underset{\{r\}}{\text{Maximize}} \int_0^r u(i)di - ru(r)$$

subject to: $c \geq u(r) - v(r) \geq 0$.

This quantity is maximized by increasing r as much as possible -- this means **the solution occurs when $u(r) = v(r)$; i.e., $r = r_o$.** This means I = 0 and case **(iii) reduces to free entry.**

DISCUSSION

In short, either there is free entry (the government sets the fine low enough so that no inspection takes place), or the government sets the fine high enough that the following occurs: the inspector collects the fine from everybody who uses the public good. The fine is set in a second best fashion: it equates the sum of marginal inspection cost and marginal social cost of crowding. The optimal number of participants is given by equation (3), which states that the marginal user's benefits must be equal to the optimal fine. If we dislike having the inspector get away with the fines we can simply charge him a lump sum tax equal to the difference between the fines collected and the costs of collecting them.

Note that the outcome where exclusion occurs is second best since we must take into account the social cost of inspection. In other words, compared to the situation of costly but honest and diligent enforcement, the outcome which arises with exclusion subject to incentives for corruption consists of a smaller number of participants and a greater expected fine for usage.

When is this outcome socially desirable? The arrangement with exclusion and overenforcement is socially desirable if and only if it leads to a greater social welfare than the social welfare obtained with free entry. Formally, the condition is:

$$r^{**} c < r_o v(r_o) - r^{**} v(r^{**}) - \int_{r^{**}}^{r_o} u(i)\,di \qquad (4)$$

that is, the social cost from overenforcement (left side of (4)) must be smaller than the net social gains of exclusion (right side of (4)), which are given by the total benefits from reduction of crowding net of total benefits foregone with exclusion.

THE EFFECTS OF A QUOTA SYSTEM ON INSPECTIONS

Now suppose the government can mandate users who are caught by the inspector to appear in court. The inspector is paid the fine if and only if the individual brought to court is convicted. Given the irrefutable evidence (i.e., a photograph) users who are taken to court are surely convicted. Given also that no individual who is taken to court is convicted without evidence, nonusers are not penalized (i.e., there is no Type I Error). Thus, the government knows the total usage of the lake whenever the inspector catches all users. Is there any way for the government to improve upon the allocation where the inspector catches all users if the government knows the extent of inspections? Can the government reduce the number of inspections and still maintain the incentive compatibility of the arrangement? Is there a policy rule which leads to first best usage while reducing simultaneously fines and the number of inspections?

Let us examine the effects of a policy rule which aims to reduce the incentives to the inspector. Suppose now the inspector's (formerly lump sum) reimbursement depends on the number of offenders who are prosecuted. Specifically, let the reimbursement be R if Q individuals come before the court and $-\infty$ otherwise.[4] Thus, the inspector always chooses $I \geq Q$ for any $r \in [0, P]$. The government's problem is then to find I, Q, r and f to:

$$\text{Maximize } \int_0^r u(i)di - rv(r) - Ic \tag{P4}$$

subject to: $u(r) - v(r) = If/r$,

$I \in [Q, r]$

$f > c$ implies $I = r$

$f < c$ implies $I = Q$

$f \geq 0$, $Q \geq 0$.

In this problem, we can show that the addition of a quota to the available instruments yields no increase in social welfare. To see this, we will consider each case in turn. If $f < c$, then either $I = 0$ (free entry) or social welfare is improved by increasing f (and decreasing I correspondingly) until $f = c$. If $f = c$ then we can, without loss of generality, set $Q = I$, but then the problem reduces to the corresponding case of (P3.2) and free entry is again optimal. Finally, if $f > c$, then $I = r$ and the level of Q is irrelevant. Again, the solution is identical to the corresponding solution of (P3.1).

In sum, Q is ineffectual. If fines are high (i.e., $f > c$), the government cannot achieve the results with a rule whereby not everybody is to be fined since users become prey to the inspector. So fines cannot be pushed above c unless Q is set equal to r and the inspector has to fine everybody. If we do that, however, we can achieve the second best in a way that means no bribes are actually collected: we simply set the quota, Q, equal to r and pay the inspector cr. Note that even though no bribes are paid the threat of bribery forces an inefficiency on the economy, and the net result is identical to that described in the previous section.

PRIVATE ENFORCEMENT OF EXCLUSION BY A MONOPOLIST

For comparison, consider a case where the rights to exclude people from usage are sold to a monopolist. Suppose the only control the government exerts over the inspector is in setting the price for exclusion rights.

The (unregulated) inspector chooses r, f and I to:

$$\text{Maximize } r(f-c) \tag{P5}$$

subject to: $u(r) - v(r) = If/r,$

$I \in [0,r]$

$f > c$ implies $I = r$

$f < c$ implies $I = 0$

$f \geq 0.$

Note that since the objective function increases with f, the inspector chooses $f > c$ and thus $I = r$. Therefore, the inspector's problem becomes one of choosing r and f to maximize the following Lagrangian:

$$L = r(f-c) + \lambda[u(r) - v(r) - f].$$

The following first order conditions determine r_m and f_m, the solution to (P5):

$$u(r_m) - v(r_m) = f_m, \tag{5}$$

$$f_m = c + r_m v_r(r_m). \tag{6}$$

Condition (5) shows that r_m is the level of usage which equates the marginal user's benefits to fm, the price charged for usage. Condition (6) states that the price must be equal to the marginal social cost of usage, which in turn is equal to the sum of marginal inspection cost and marginal social cost of crowding. It follows that the monopolist's arrangement is the same as the government's arrangement where exclusion is desirable. (Compare conditions (5) and (6) with (3) and f^{**}.) Indeed, if the government dislikes the inspector to make profits, it can set the price for the exclusion rights equal to $r_m(f_m \cdot c)$.

The equivalence between the monopolist's arrangement and the second best arrangement results from the fact that individuals agree on the costs of crowding. We conjecture that if individuals disagreed on these costs, the monopolist would charge a greater price and thus would attract fewer users than would be efficient.

CONCLUSION

In a world of costly deterrence but no corruption a clever use of fines will solve the problems of optimal exclusion. In the presence of corruptible enforcers, however, fines cannot be set sufficiently high to make randomized enforcement possible. In these cases the optimal arrangement is either to abandon enforcement entirely or to set the fine equal to the sum of marginal cost of inspection and marginal social cost of crowding and have all participants pay the fine. In effect this is equivalent to private enforcement of exclusion by a monopolist when individuals agree on the cost or crowding.

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ADDENDUM: LICENSE FEES AND HETEROGENEOUS USERS

In the model of the paper, it is assumed that, although fines can be levied, the government does not directly tax the use of the lake, through license fees, or the like. This section examines the effect of including a license fee in the government's arsenal of regulatory tools. We find that if the model is unmodified but a license fee is allowed, the government can again approximate the first best outcome by letting the fine go towards infinity, even if the monitors are not honest and diligent. However if we add nufficient heterogeneity of consumers into the model the results hold as before: infinite fines imposed with near zero probability achieve first best if the monitor is honest and diligent, but fines must be set at a lower level to deter overenforcement in a second best manner if monitors are not honest and diligent.

Specifically we introduce heterogeneity in two dimensions: ease of inspection and size of externality imposed. Assume potential users of the lake are of one of two types: high-powered boaters and low-powered boaters. Boaters of each type impose externalities on all users of the lake. Suppose that r^h high-powered boaters and r^l low-powered boaters are using the lake. Then the utility to individual i^h among the high-powered boaters of using the lake is

$$u^h(i^h) = v^h(r^h) - w^h(r^l)$$

and the utility to individual i^1 is

$$u^l(i^l) = v^l(r^l) - w^l(r^h)$$

In other words, $u^j(i)$ is the idiosyncratic utility of the ith person of type j using the lake, v^j is the disutility imposed on type j users by type j users and w^j is the disutility imposed on type j users by the other type.

The first best allocation in this world maximizes

$$\int_0^{r^h} u^h(i)\,di + \int_0^{r^l} u^l(i)\,di - r^h(v^h(r^h) + w^h(r^l)) - r^l(v^l(r^l) + w^l(r^h))$$

The first order conditions for this maximization are

$$u^h(r^h) - v^h(r^h) - w^h(r^l) = r^h\, v^h_r(r^h) + r^l\, w^l_r(r^h)$$

$$u^l(r^l) - v^h(r^h) - v^l(r^l) = r^l\, v^l_r(r^l) + r^h\, w^h_r(r^l)$$

where in each case, the right side equals the social cost. Let r^{h*} and r^{l*} represent solution to these equations; for simplicity assume the solution is unique and optimum is interior. If the two types could be distinguished and different fees imposed on each and enforcement were perfect and costless, then the first best could be achieved by setting their license fees equal to the right sides of the respective equations.

Whether an individual who uses the lake chooses to pay the license fee or risks being caught without a license depends on the relative costs of the two and the probability of being caught. Suppose the license fee is t, the probability of detection is p, and the fine if detected is f. Then an individual will choose to risk a fine rather than buy a license if

$$t > p\,f$$

and individual with characteristics (i,j) will find it desirable to use the lake if

$$u^j(i) - v^j(r^j) - w^j(r^{-j}) > \min(t, pf)$$

(where here and in what follows -j = h if j = 1 and vice versa)

Let the cost of inspection be c^j for a boat owner of type j. Then the government objective is to maximize

$$\int_0^{r^h} u^h(i)\,di + \int_0^{r^1} u^1(i)\,di - r^h(v^h(r^h) + w^h(r^1)) - r^1(v^1(r^1) + w^1(r^h)) - I^h c^h - I^1 c^1$$

where I^j is the number of inspections made of boaters of type j. Let e^j be the fraction number of boaters of type j who chose not to pay the license fee, and let r^j be the marginal user of type j. In principal, it might be advantageous to have separate license fees and penalties for each type of boater, but we will show that the first best can in fact be achieved with a single license fee t and a single fine f for all boaters. The government's objective is to maximize the above expression by choosing

$$\{f, t, (r^j, e^j, I^j)_{j=h,1}\}$$

subject to the following conditions:

$$u^j(r^j) - v^j(r^j) - w^j(r^{-j}) = \min(t, fI^j/r^j)$$

$$r^j \geq I^j \geq 0$$

$$f \geq 0$$

$$t \geq 0$$

$$1 \geq e^j \geq 0$$

If $t > fI^j/r^j$ then $e^j = 1$

If $t < fI^j/r^j$ then $e^j = 0$

The first condition describes the user's incentive to use the lake or not; the last two conditions describe the user's incentive to pay for the license or not. Let us assume that

$$r^{h*} v^h_r(r^{h*}) + r^{l*} w^l_r(r^{h*}) < r^{l*} v^l_r(r^{l*}) + r^{h*} w^h_r(r^{l*})$$

In other words, in the first best arrangement, a low-power boater imposes a greater negative externality than a high-power boater.

<u>Result:</u> The following arrangement achieves an outcome arbitrarily close to the first best as f approaches infinity:

$$r^h = r^{h*}$$

$$r^l = r^{l*}$$

$$t = r^{l*} v^l_r(r^{l*}) + r^{h*} w^h_r(r^{l*})$$

$$I^l = tr^{l*}/f$$

$$e^l = 0$$

$$I^h - r^{h*} v^h_r(r^{h*}) + r^{l*} w^l_r(r^{h*})\ r^{h*}/f$$

$$e^h = 1$$

In other words, in this arrangement, there is in general a higher probability of catching low-powered boaters than of catching high powered boaters. Because of this difference, low-powered boaters prefer to pay the license fee; high-powered boaters prefer to free ride. Each however, pays the correct fee in expectation to ensure that the number of each type conforms to the first-best. As the penalty approaches infinity, the frequency of inspection necessary to achieve the first best approaches zero.

The Maximization Problem when the Inspector is Neither Honest Nor Diligent

The requirement that taxes and fines be the same for all types of boaters becomes necessary if inspection is delegated to the inspector and the inspector has superior information to the court. In other words, assume that when people come in to purchase licenses the government cannot make an exogenous distinction between high-powered boaters and low-powered boaters. Furthermore, assume that the photograph submitted as evidence of usage of the lake cannot distinguish between high-powered and low-powered boats. Then the fine for not having a license must be identical for the two types of boaters; and therefore the price of the license must be the same as well.

In this environment, taking (f, e^h, e^l, r^h, r^l) as exogenous, the inspector chooses (I^h, I^l) in $[0, r^h] \times [0, r^l]$ so as to maximize

$$I^h(e^h f - c^h) + I^l(e^l f - c^l)$$

Therefore, the inspectors incentives translate into the following additional constraints on the government's maximization problem.

If $e^j f > c^j$ then $I^j = r^j$

If $e^j f < c^j$ then $I^j = 0$

The crucial assumption we make is that there is negative correlation between the cost of inspection and the external damage imposed. For the example we are examining, this means that the cost of inspection is higher for high-powered boats.

The remainder of this note analyzes the problem in the case where $c^l = 0$, and $c^h > 0$. In this case it can be demonstrated that there is no loss of generality in assuming that $f \geq t$ in the optimum and $e^l = 0$ and $I^l = r^l$. This is not surprising: when one type of inspection is costless, the inspector is willing to make those inspections and as a result, all users of that type pay for the license with certainty. Furthermore, it can be shown that as long as $c^h > 0$, the inequality

$$t < fI^j/r^j$$

is inconsistent with the other conditions on the problem. (Full compliance requires positive probability of inspection, which is inconsistent with full compliance if inspection is expensive.) Therefore we may rewrite the maximization problem in the following simplified form:

(Problem Al): Choose $\{f,t,r^l,r^h,e^h,I^h\}$ to maximize

$$\int_0^{r^h} u^h(i)\, di + \int_0^{r^l} u^l(i)\, di$$
$$- r^h(v^h(r^h) + w^h(r^l)) - r^l(v^l(r^l) + w^l(r^h)) - I^h c^h - I^l c^l$$

subject to

$$u^l(r^l) - v^l(r^l) - w^l(r^h) = t$$

$$u^h(r^h) - v^h(r^h) - w^h(r^l) = fI^h/r^h$$

$$r^h \geq I^h \geq 0$$

$$f \geq t \geq 0$$

$$e^h \geq 0$$

$t \geq fI^h/r^h$, $e^h \leq 1$ with complementary slackness

If $e^h f > c^h$ then $I^h = r^h$

If $e^h f < c^h$ then $I^h = 0$

We divide the problem into subcases:

<u>Case I:</u> I^h 0

In this case there is free entry for high-power types (in this case w.o.l.o.g. we can set $f = t$, and $e^h = 1$). The optimum among the high-power free entry solutions can be found as follows:

(Problem A2): Choose r^h, r^l to maximize

$$\int_0^{r^h} u^h(i)\,di + \int_0^{r^l} u^l(i)\,di$$
$$- r^h(v^h(r^h) + w^h(r^l)) - r^l(v^l(r^l) + w^l(r^h))$$

subject to $u^h(r^h) - v^h(r^h) - w^h(r^1) = 0$

$\quad\quad\quad\quad\quad u^1(r^1) - v^1(r^1) - w^1(r^h) \leq c^h$

Roughly speaking, in this class of candidate solutions the optimum will involve increasing the level of low powered users beyond the first best level, to offset the extreme overuse of the lake by high-powered free entry users. Thus there will In general be overuse by both classes of users.

Case ID: $I^h \geq$.

In this case the last of the conditions of the problem (Al) can be dropped and the second to last can be rewritten

$$e^h f \geq c^h, \; I^h \leq r^h \text{ with complementary slackness}$$

Further simplification can be achieved by eliminating e^h (which does not appear in the objective). The constraints of the problem in this case are equivalent to the following constraints on the parameters other than e^h:

$$u^1(r^1) - v^1(r^1) - w^1(r^h) = t$$
$$u^h(r^h) - v^h(r^h) - w^h(r^1) = fI^h/r^h$$

$$I^h \geq 0$$
$$f \geq t \geq 0$$

$$f \leq tr^h/I^h, \; f \geq c^h \text{ with complementary slackness}$$

Thus the solution splits into two subcases:

Subcase 1: $f = c^h$:

In this case the monitor is indifferent between monitoring and not monitoring the high-powered boaters. The constraints on the remaining parameters reduce to the following:

$$c^h \geq u^l(r^l) - v^l(r^l) - w^l(r^h) \geq$$
$$u^h(r^h) - v^h(r^h) - w^h(r^l) = c^h I^h / r^h$$

$$I^h \geq 0, \; r^h \geq 0$$

Note that the solution to this problem cannot be first best in general, since the bound on f means that if I^h approaches zero, the solution approaches free entry for high-powered types.

Subcase 2: $f = tr^h/I^h$

In this case the effective deterrence is the same for both high-power and low power types. The constraints can be rewritten as follows:

$$u^l(r^l) - v^l(r^l) - w^l(r^h) = t$$
$$u^h(r^h) - v^h(r^h) - w^h(r^l) = t$$
$$fI^h = tr^h$$
$$f \geq t \geq 0$$
$$f \geq c^h$$

Since we have therefore abandoned the use of fines and taxes to differentiate among types of users, there is leeway to reduce the cost of the arrangement by letting f approach infinity while I^h approaches zero, but holding their product equal to tr^h. Such an increase in f violates no constraints. In short the optimal arrangement of this form is arbitrarily close to the optimal arrangement with zero cost of enforcement but subject to the constraint that the tax imposed on each type be identical.

For example, if the two types were such that in the first best allocation, the taxes imposed on each type were identical, then this first best allocation could be achieved arbitrarily closely by letting fines approach infinity in the manner described here. In particular, if the two types are indistinguishable (that is, if we collapse the model to the single type model of the rest of the paper) then the use of fines and taxes together will be able to achieve the first best by having the tines increase towards infinity. However, if there is a sufficiently large welfare loss associated with not discriminating between the two types in their effective tax rates imposed on them, then the second best allocation will not be of this form, but of one of the other two subcases described before, and the optimum will not involve infinite punishments.

Calculation of an Example

Consider the case where $w^h(.) = w^l(.) \equiv n$. Then in the first best calculations r^{j*} is defined as follows for j = h, 1:

$$u^j(r^{j*}) - v^j(r^{j*}) = r^{j*} v^j_r(r^{j*})$$

so that the first order conditions for each type are identicnl to the first order condition for (P1) in the simplified model of the main text. Assume $v^h_r(r^{h*}) < v^l_r(r^{l*}) < c^h$

Free entry conditions are also identical to those of the simpler model of the main text:

$$u^j(r^j_0) - v^j(r^j_0) = 0.$$

The first best can be achieved with costly enforcement if the inspector is honest and diligent. If he is not, then we can consider the three sub cases of the solution to problem (Al) of this appendix:

Case I: $(I^h = 0)$: $r^l = r^{l*}$

$r^h = r^h_0$,

In other words, the low-powered types receive the first-best allocation; the high-powered types receive the free-entry allocation. (If we were instead to assume that $v^l_r(r^{l*}) > c^h$, then the optimum for this case would satisfy: $v^l_r(r^l) = c^h$.)

Case 11.1: In this case the search for the optimal value of r^h is identical to the calculation of case iii in problem (P3) of the main text: the optimal level of $r^h = r^h_0$ so that the complete solution can be no better than the solution in case I: free-entry for the high-powered types and first-best for the low powered types.

Case 11.2: In this case the (common) expected tax on the two types lies between the first best tax on the low-powered type and the (lower) first best tax on the high-powered type. Thus relative to first best, there will be too many low-powered types using the lake and too few high-powered types. As we make the social cost of increasing the number of low powered types sufficiently large (for example, as we make low-powered types a greater portion of the total population) we will find that the optimum tax in this sub case approaches the first best tax for low-powered types. As this happens the optimum in this sub case is eventually dominated by the optimum of case I.

In summary in this example, as long as there is sufficient social cost to imposing the same effective tax on both types of individuals, the social optimum involves imposing the first best level of tax on low-powered types and letting the high-powered types enter freely, without paying the tax. To ensure this will hold, it is necessary to make the fine f no more than c^h, so that the inspectors will have no incentive to attempt to catch high-powered violators.

Thus, for high powered types the main outcomes of the text are parallel to the outcomes of the example in this appendix: either there is free entry of high powered types or there is too much restriction of the high-powered types relative to first best.

FOOTNOTES

[1] Becker and Stigler analyze two ways to circumvent this puzzle. First, instead of paying the enforcer the extra compensation, the state can demand that a prospective enforcer pay an "entrance fee" or bonus equivalent to this extra compensation in order to be awarded the job. The state then pays the enforcer his opportunity wage plus interest on the bond as long as he is employed and it returns the bond when he retires. If the enforcer misbehaves and is caught, he is fired and forfeits the bond. One problem with this is that for large entrance fees there will be incentives for the state to fire enforcers without cause so as to keep the fees. If the enforcer's contract is contingent on this possibility his salary will have to increase even further. Another problem with the proposal is that for large entrance fees enforcers, even when guilty of corruption, have incentives to appeal the state‘s decision or demand compulsory hearings on dismissal in order to retain their bonds. The second way is simply to permit corruption. As enforcers anticipate corrupt opportunities, they might be willing to accept enforcement jobs that pay less than the opportunity wages. The shortcoming of this proposal, however, is that the social costs of corruption (e.g. enforcer's effort or time to conceal evidence of corruption, the harm to others, etc.) are usually greater than the benefits it brings to corrupted enforcers.

[2] There might still be some incentives for enforcers in enforcement firms to accept or demand bribes from violators if rewards are divided among enforcers or if the enforcers doing the field work are not the owners of the firm.

[3] Landes and Posner (1975) investigated the extent to which private enforcement is efficient. They examined the efficiency of enforcement conducted by competitive firms as well as by a monopoly. In their model enforcement firms benefit from their effort by keeping toe proceeds from convictions. They found that although a monopoly does better than competitive firms, privatization of enforcement leads to more enforcement than is socially desirable. The problem is that once fines become rewards, whenever the state sets sufficiently large fines in order to deter violations, it stimulates too much enforcement activity. By the same token, whenever the state sets sufficiently low fines, too little private enforcement results.

[4] The results would be the same if the government adopts the following set of incentives:

$f > c$ for $r \leq Q$

$f = 0$ for $r > Q$.